

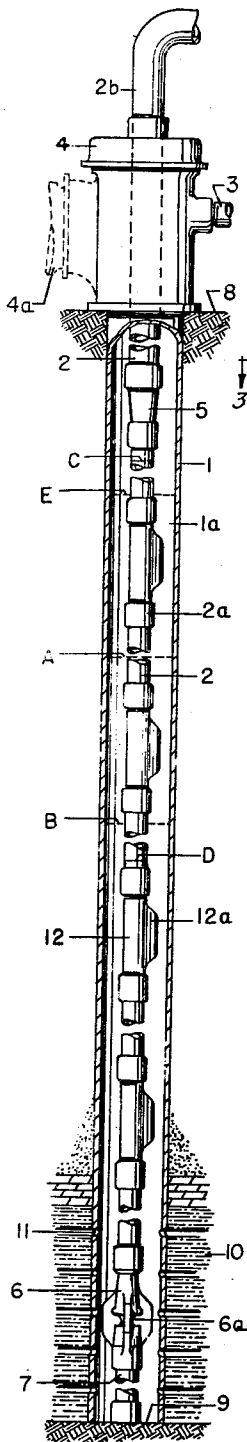
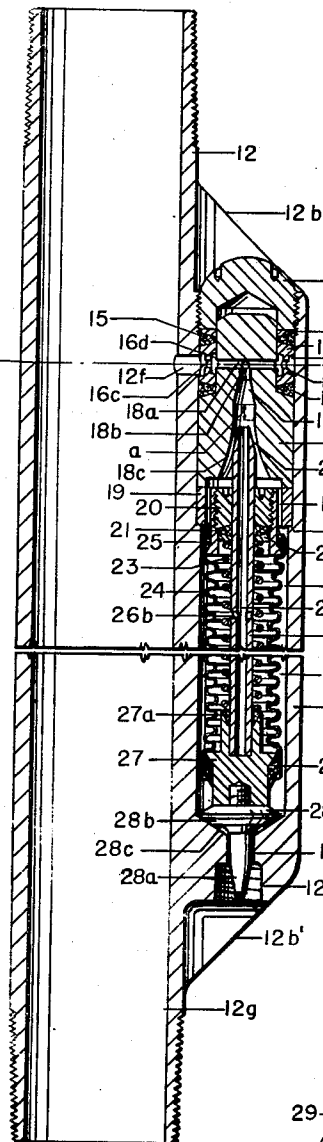
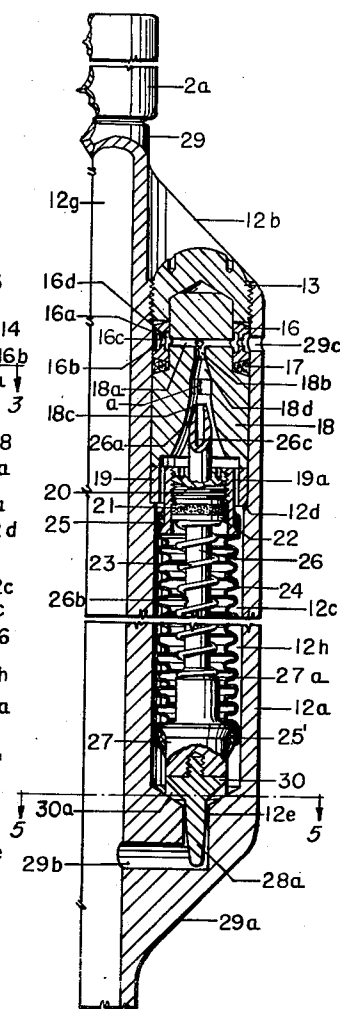
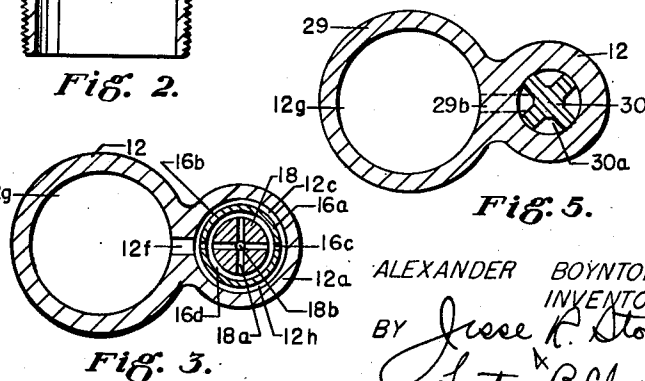
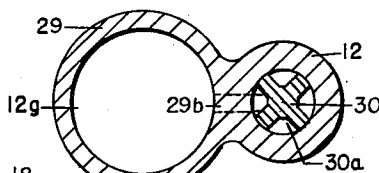
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DIFFERENTIAL STAGE LIFT FLOW DEVICE

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DIFFERENTIAL STAGE LIFT FLOW DEVICE

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7 Claims. (Cl. 137-111)

My invention relates to devices for flowing wells by compressed air or gas.

The principal object is to discharge well liquid from wells by employing pressure fluid of relatively low value with resulting low gas-oil ratios.

In accomplishing the foregoing object, another object is to employ unusually great force in actuating the valves for the purpose of accomplishing positive valve action and leak-proof valve seating.

A further object is to provide a valve that will not admit pressure fluid into the tubing in response to temporary high pressure areas therein.

Another object is to provide a durable flowing device of simple construction which is easily adapted to flow through either the tubing or the casing.

A metallic bellows is anchored at one end and has a valve attached to the other end within a chamber communicating between the interior and exterior of an eduction tube within a well casing. The free end of the bellows actuates a valve open at low difference in pressures within and without the eduction tube and closed at relatively great difference in such pressures. The difference in these pressures is caused by a restricted passage limiting the flow of pressure fluid through the chamber surrounding the bellows. The outside of the bellows is exposed to the relatively high pressure on the high pressure side of the partial barrier in the chamber which surrounds the bellows; while the inside of the bellows is exposed to the low pressure side.

I attain the foregoing objects by mechanism illustrated in the accompanying drawing in which—

Fig. 1 is a broken side view partly in section showing an installation of the devices in a well.

Fig. 2 is a longitudinal section through the preferred embodiment of the invention for tubing flow.

Fig. 3 is a cross section on the line 3-3, Fig. 2. Fig. 4 is a vertical section of a modified form of the invention adapted for casing flow.

Fig. 5 is a cross section on the line 5-5, Fig. 4. Similar characters of reference are employed to designate similar parts throughout the several views.

The difference in pressures obtaining at any time within the tubing and in the annular space 1a between the tubing and the casing will be referred to as the differential, that being the force which controls the movements of the valve 26a.

The column of well liquid which stands up in the tubing above the liquid level in the casing, due to the presence of pressure fluid in the annu-

lar space 1a will be referred to as the upstanding column. Likewise, the column of well liquid which stands up in the casing above the liquid level in the tubing, due to the presence of pressure fluid in the tubing, will also be referred to as the upstanding column.

It will be understood that liquid flow from the well will result from introduction of compressed air or gas into the upstanding column, which will be elongated by the expansion of the pressure fluid so introduced.

The valve stem 26, the bellows 24, and all parts actuated by movement of the free lower end of said bellows will be designated as the movable assembly. It will be noted that this assembly is anchored proximate the upper end of the bellows and that the valve is attached to and is actuated by the movement of the free end.

In Figs. 2 and 4, the body 12, which may be cast or otherwise fabricated integrally with the tubular housing 12a, has a passage 12g of the same size as the tubing bore and aligned therewith. The bore 12c within the housing 12a has an annular space 12h between the bellows and the wall of the bore. This clearance space may be such as $\frac{3}{8}$ to $1\frac{1}{8}$ inch while the over-all diameter of the bellows may be, for example, such as $1\frac{1}{8}$ to $1\frac{1}{2}$ inches.

The bellows 24 is housed within the bore or chamber 12c and is supported at the upper end by an anchor 19 which may be engaged upon the slight internal annular shoulder 12d of the housing and secured there by the valve seat member 18 which is itself urged downward by the plug 13, having threaded engagement within the upper end of the shell or housing 12a. The plug thus exerts a securing force upon the gland ring 14, the packing 15, the sleeve 16, and the packing 17. These parts form a hermetic barrier between the annular space 1a, Fig. 1, and the opening 12f, except through the openings 12e' and 12e at the lower end of the housing; the passages 12h, 19a, 18c, 18b, 18a, 16d, 16c, and 16b. The size of these openings should be equal to or somewhat larger than the greatest clearance between the valve stem 26 and the opening 18c. The valve 26a, formed upon the upper end of the stem 26, is adapted to prevent passage of pressure fluid through the openings above mentioned by closing upon the seat 18d when the differential compresses the bellows, as will be more fully explained. The lower end of the bellows is closed by a lower end connection 27 to which is secured a check valve member 28. The open space 28c

under the check valve 28b is provided in order to expose a relatively large area of the member 28 to the differential pressure entering through the passage 12e below the check valve. The valve stem 26, having its upper end positioned within the tapered bore 18c, has its lower end secured at the free lower end of the bellows within said end connection 27.

The tubular web 16a connecting the enlarged ends of the member 16 and having the openings 16c, provides two small annular chambers, one on either side of the web, the chamber 16b being between the web and the shell 12a and the other chamber 16b being between the web and the member 18, as appears in Figs. 2, 3 and 4.

The bellows is secured upon its anchor 19 by the solder or weld 25 and secured upon its lower end connection 27 by the solder or weld 25'. The valve stem 26 may be secured within an upward extension of the member 27 by the weld 27a. This stem is closely slidable within the central opening through the bushing 20, the packing 21, and the gland ring 22. The coiled spring 23, preferably installed under some compression, engages between the upper extension of the member 27 and the gland ring 22 and is freely slidable over the stem 26. The gland ring 22, slidable within the member 19, compresses the packing 21 by force of the spring 23. Lateral openings 26b and the central opening 26c formed in the stem 26 serve to equalize the pressure within the bellows with the pressure within the opening 18c.

The check valve member 28 has a downward axial extension forming a governor pin 28a. Said governor pin and check valve member 28, formed into a check valve at 28b above the pin, has threaded engagement within the member 27.

The concavely tapered central opening 18c has, proximate the seat 18d, a straight portion a having a diameter only slightly greater, such as one-thousandth of an inch, than the outside diameter of the untapered stem 26, which may be $\frac{1}{8}$ to $\frac{1}{2}$ inch; while the diameter of the opening 18c at its lower end, may be such as $\frac{1}{8}$ to $\frac{1}{4}$ inch greater than the outside diameter of the stem 26. The valve-like relation between the valve stem 26 and the untapered portion a provides that the valve will not fly open when slugs of well liquid pass through the tubing 2 during the flowing operation. A similar construction may be employed in Fig. 4.

The convexly tapered pin 28a proximate its upper end, may have only slight clearance, such as two- to five-thousandths of an inch, within the upper end of the passage 12e; while the lower portion of this pin will have a clearance of $\frac{1}{8}$ to $\frac{1}{4}$ inch within this passage when the valve 26a is seated at 18d. It, therefore, will be observed that the clearance between the stem 26 and the opening 18c will be diminishing, while the clearance between the passage 12e and the pin 28a is increasing, as the valve 26a approaches its seat 18d, and vice versa. This arrangement for decreasing one opening while increasing the other will allow the greatest flow of pressure fluid into the upstanding column in the tubing at approximately one-half the differential required to completely seat the valve 26a. If it be desired to admit a greater amount of pressure fluid into the tubing at lower differentials, the pin 28a may be made smaller or wholly omitted.

The threaded opening 12e' is for connection of a testing means which may be employed to check the valve adjustments.

It will be understood that the yieldable metallic bellows 24 and the spring 23 are adapted to be compressed sufficiently to allow the valve 26a to seat at the proper differential, this being somewhat more than the force per square inch exerted by the well liquid between adjacent devices, in order that the next upper valve will remain open until the next lower valve is uncovered by the receding liquid level. The devices may be spaced from 150 to 300 feet apart in the tubing string.

The valve 26a, formed upon the upper end of the stem 26, is positioned centrally of the tapered bore 18c and may be spaced at a distance such as $\frac{5}{8}$ " to 1" away from the seat 18d. This valve is normally open as shown in Figs. 2 and 4, until closed by the differential, and has progressively less clearance around it while moving toward its seat 18d. The check valve 28 is lightly seated upon the lower extremity of the bore 12c in order to prevent regress of the well liquid through the device at conclusion of the flowing operation. A check valve may be placed in the tubing proximately above the nipple 6 to complete the entrapment of such liquid in the tubing.

In the operation of both forms of this device, there are three forces which govern the valve movements. The pressure fluid exerts the only force constantly urging the valve toward its seat 18d; while the expansive force of the bellows and spring, plus the force exerted by the upstanding column above the device, are the forces constantly urging the valve away from its seat.

Manifestly, each of these forces is constant, and predetermined, except the resistance of the upstanding column, which, of course, will vary at each device, depending upon the distance between the device and the base of the upstanding column. At the base of the upstanding column, these opposing forces are equal, and the valve in a device there will be open, as in Figs. 2 and 4. If, on the other hand, a device is positioned in the tubing at such distance above the base of the upstanding column that the portion of fluid in that column between its base and the device weighs, per square inch, exactly as much as the per square inch force required to close the valve, then that valve will be just closed. Higher devices will have their valves closed by increasing force with increasing height of their positions in the upstanding column or above it. Each lower device will have its valve increasingly wider open as its position approaches the base of the upstanding column.

The pressure fluid acts upon the exterior of the bellows to compress it; whereas, the force of the upstanding column acts within the bellows to aid the spring and the bellows in resisting compression of the bellows.

In Fig. 2, the pressure fluid enters the chamber 12h to contact the exterior of the bellows via passages 12e', 12e, and the space 28c, where it lifts the check valve member 28, and passes upward through the clearance, such as $\frac{1}{32}$ inch between the latter member and the wall of the bore 12c.

The back pressure of the upstanding column enters the bellows via the passages between the openings 12f, and 26b, as appears in Fig. 2, the latter openings communicating with the interior of the bellows.

The value of the pressure fluid, preferably, should be at least two or three times the force required to seat the valve 26a, and may be of much greater, depending upon the depth from

which the well is being flowed, the volume of well liquid, and other well conditions.

The rate of flow will be increased as the value of the pressure fluid employed to accomplish flow is increased, and vice versa; although the rate of increased flow, due to friction and the laws governing energy given off by expanding gases, will not be in direct proportion to the increased value of the pressure fluid.

For flowing the well through the tubing, reference is made to Fig. 1, wherein the tubing 2 of two different sizes is joined together by the swaged nipple 5 in the upper regions of the well. The casing head 4 is employed to accomplish a hermetic seal between the well casing 1 and the tubing 2 proximately above the ground surface 8. The anchor string 7 may extend from the nipple 6 to the bottom of the well 9. Well liquid enters the tubing through the lateral opening 6a. The gun perforations 11 admit into the casing well fluid from the producing formation 10. The flow devices 12 are joined into the tubing by couplings 2a, the sloping ends 12b and 12b' being to guide the devices in passing deformities frequently found in well casing.

If the well does not produce enough gas to flow it, pressure fluid may be supplied into the annular space 1a through the line 3, but if the well produces enough gas to flow it, the opening in the casing head occupied by the line 3 may be closed by a plug, unless the line should be needed to convey surplus gas from the well.

The casing flow line 4a and means for connecting it to the casing head, indicated by dotted lines, will be disregarded for the time being as if not shown.

The flow line 2b is supposed to be closed by an unshown valve and pressure fluid of proper value is assumed to be in the annular space 1a.

Now, to flow the well through the tubing, open the unshown valve in the flow line 2b. This will at once draw off the pressure fluid in the tubing, close all valves in the devices, and depress the well liquid from its normal level at A in both the tubing and the casing to the level B within the annular space 1a. At the same time the well liquid rises in the tubing to the level indicated at C. The device, next above the depressed level B, will be open and discharging pressure fluid into the upstanding liquid column in the tubing, because the differential there will not be sufficient to close the valve 26a. This is true for the reason that the bellows and spring 23 will not compress enough to seat the valve 26a unless the differential be greater than the weight per square inch of the liquid column between the valves, as previously stated.

The globules of pressure fluid admitted into the upstanding column expand during their upward travel through the tubing and thereby elongate the upstanding liquid column into and through the flow line 2b.

As the liquid level is lowered in the annular space 1a, by and during the flowing operation, the valves in the upper devices will close in progression downward, due to the downward movement of the level where the pre-determined differential necessary to close the valves obtains; while each lower valve will be open when uncovered by the receding well liquid, due to the slight differential obtaining there.

The well, therefore, will flow by stages, and at relatively low pressures with resulting comparatively low gas-liquid ratios due to the power

medium being metered to the load as previously explained.

The device illustrated in Fig. 4, which is an adaptation for casing flow of the device shown in Fig. 2, has all of its parts identical with the preceding form, except that the body 29 and the governor pin member 30 are somewhat different from the corresponding parts 12 and 28, respectively, in Fig. 2.

The tubular body 29 in Fig. 4 is identical with the body 12 in Fig. 2, except for the opening 29b, which communicates between the passages 12g and 12e, replacing the threaded opening 12e', and except for the other opening 29c which communicates between the annular spaces 1a, Fig. 1, and 16b, Figs. 2 and 4, and further excepting the lower tapered end 29a.

The governor pin member 30 has the openings 30a to admit pressure fluid freely from the opening 29b into the annular chamber 12h.

It will be understood that all parts not indicated as different from those in Fig. 2 will be the same as in Fig. 2. It will be also understood that the force required to compress the bellows 24 and the spring 23 far enough to seat the valve 26a is, likewise, the same in both constructions.

The path of the pressure fluid going out of the tubing is through the lateral opening 29b, through the annular space in the passage 12e, through the openings 30a, around the bellows, through the annular space 12h, through the openings 19a, 18c, and the other openings as in Fig. 2 until the exit into the annular space 1a is made through the lateral opening 29c.

In Fig. 4, the back pressure of the upstanding column in the casing contacts the interior of the bellows through the lateral opening 29c, the annular space 16b, the openings 16c, the annular space 16d, the openings 18a, 18b, 26c, and 26b.

The form of device illustrated in Fig. 4, adjusted and installed as stated for Fig. 2, will now be considered as spaced at intervals in the tubing string in Fig. 1 to flow the well through the casing, in place of the devices shown there for tubing flow.

The line 3 will be considered as replaced by a plug in the casing head 4. The open line 4a, indicated by dotted lines as connected into the casing head now will become the discharge conduit.

For flowing through the casing, the induction tube 2 preferably will be all of one size and of somewhat smaller diameter than that employed for flowing through the tubing.

To initiate casing flow, pressure fluid of a similar value to that previously mentioned for the tubing flow will be admitted through the line 2b into the tubing 2, it being understood that the well liquid is then standing in both the tubing and the casing at the level indicated at A. As the pressure fluid value increases in the tubing, the liquid in the tubing will become depressed to the level indicated at D, while the top of the upstanding liquid column in the casing will be at E. The device next above the depressed liquid level in the tubing will be open and discharging pressure fluid into the upstanding column in the annular space 1a, and the well will flow through the casing in a manner so similar to that described for flowing through the tubing, as to require little further explanation.

In flowing through the tubing, the pressure fluid enters the bellows chamber of the device illustrated in Fig. 2 through the opening 12e' and enters the upstanding liquid column in the tub-

ing through the opening 12f; whereas, in flowing through casing the pressure fluid enters the bellows chamber through the opening 29b and enters the upstanding column in the annular space 1a through the opening 29c. Otherwise, the operation of both devices is the same.

Manifestly, the valves in both forms of the invention may be formed or adjusted to pass more or less pressure fluid into the upstanding column as different well conditions may require. Such change may be accomplished either by increasing or decreasing the size of the openings governing the admission of the pressure fluid, or by changing the adjustment so as to cause the valve 26a to seat at a higher or lower differential. Similar results may be obtained by increasing or decreasing the value of the pressure fluid, as previously indicated.

It is also apparent that the valves in different devices of an installation may be so made as to differ from each other in the differential required to close them, as well in the volume of pressure fluid that will pass through them at the same pressure fluid value. The manner of progression in providing such changes in the valves will be suggested by well conditions to those skilled in the art.

The cross sectional area of the bellows being many times greater than the cross sectional area of the valve, as shown, it is evident that the force employed to seat the valve will be many times greater than that employed to seat valves having the same area as that of their seats exposed to the actuating force, as is now the practice in devices employed for similar purposes.

The invention as herein illustrated and described is manifestly subject to many changes in construction and arrangement of parts which will be within the scope and purpose of the stated objects and appended claims.

What is claimed is:

1. In a stage lift device, a valve body, a vertically extending housing thereon having openings at its opposite ends leading respectively to the interior and the exterior of said body for the passage of a pressure fluid therethrough, a bellows diaphragm in said housing anchored at its upper end to the housing and having its lower end free, a lower valve connection closing the lower end of said bellows diaphragm, a check valve on said connection adapted to seat in the lower opening in the housing, a valve seat adjacent the upper end of said housing, said seat being connected with the upper opening, a tubular cylindrical valve stem connected with said lower valve connection and normally projecting upwardly through the upper end of the bellows diaphragm to a point adjacent said upper seat, a valve on said stem, said stem having lateral ports therein within said diaphragm whereby pressure of fluid at said upper opening may be exerted within said bellows diaphragm, and passages upwardly from said lower opening about said bellows to said upper opening.

2. In a stage lift device, a valve body, a vertically extending housing thereon having openings at its opposite ends leading respectively to the interior and the exterior of said body for the passage of a pressure fluid therethrough, a bellows diaphragm in said housing anchored at its upper end to the housing and having its lower end free, a lower valve connection closing the lower end of said bellows diaphragm, a check valve on said connection adapted to seat in the lower opening in the housing, a valve seat ad-

5 adjacent the upper end of said housing, said seat being connected with the upper opening, a tubular cylindrical valve stem connected with said lower valve connection and normally projecting upwardly through the upper end of the bellows diaphragm to a point adjacent said upper seat, the upper end of said cylindrical stem being tapered to form a valve to engage said seat, a cylindrical area below said seat into which said stem slidably engages to prevent sudden surges of fluid past said valve, a passage through said stem to the interior of said diaphragm, the outer surface of said bellows being exposed to fluid pressure from said lower opening when said check valve is unseated.

3. In a stage lift flow device for wells, a valve body having an opening, a housing on said valve body one end of which communicates with said opening, the other end of said housing having an opening to the outside, an upper valve seat member in said housing, an upwardly tapered recess in said member forming a seat connected with the uppermost of said openings, a bellows diaphragm in said housing below said valve seat member, an anchor therefor at the lower end of said seat member, said anchor having passages outside said bellows diaphragm to said recess, a tubular valve stem, a support therefor closing the lower end of said bellows diaphragm, said stem fitting slidably through said anchor and adapted to engage said seat, said stem having openings therein, and means movable with said diaphragm to close the other of said openings when said valve is fully opened.

4. In a stage lift flow device for wells, a valve body having an opening, a housing on said valve body one end of which communicates with said opening, the other end of said housing having an opening to the outside, an upper valve seat member in said housing, an upwardly tapered recess in said member forming a seat connected with the uppermost of said openings, a bellows diaphragm in said housing below said valve seat member, an anchor therefor at the lower end of said seat member, said anchor having passages outside said bellows diaphragm to said recess, a tubular valve stem, a support therefor closing the lower end of said bellows diaphragm, said stem fitting slidably through said anchor and adapted to engage said seat, a fluid conduit from the uppermost of said openings to the interior of said diaphragm, and means operating when said bellows is fully expanded to close the other of said openings.

5. In a stage lift flow device for wells, a valve body having an opening, a housing on said valve body one end of which is connected with said opening, the other end of said housing having an opening to the outside, an upper valve seat member in said housing, an upwardly tapered recess in said member forming a seat connected with the uppermost of said openings, a bellows diaphragm, an anchor therefor at the lower end of said seat member, said anchor having passages outside said bellows diaphragm to said recess, a lower connection closing the free end of said bellows diaphragm, a valve stem thereon extending upwardly through said anchor to said recess, a valve on the upper end thereof, said recess being formed to choke the passage of fluid thereby when said valve is positioned near said seat, means furnishing a passage for fluid from said uppermost opening to the interior of said diaphragm, and means to close the other of said openings but operating in response to fluid pres-

sure to open and permit passage of fluid through said housing.

6. A valve body, a housing thereon, a check valve seat at the lower end of said housing surrounding an inlet passage to said seat from exteriorly of the valve body, a valve seat connection in the upper end of said housing, a removable plug in the upper end of said housing to secure said connection rigidly in position, an upwardly tapering valve seat in said connection, said seat being connected by a passage to the interior of said valve body, a valve stem, valves thereon adapted to move into engagement with said seats, means supporting both said valves and operating in response to differential pressures within and outside said valve body to move said valves to open one and close the other simultaneously and means tending to hold one of said

valves normally closed upon the check valve seat.

7. A valve body, a housing thereon, a check valve seat at the lower end of said housing surrounding an inlet passage to said seat, a valve seat connection in the upper end of said housing, a removable plug in the upper end of said housing to secure said connection rigidly in position, an upwardly tapering valve seat in said connection, said seat being connected by a passage to the interior of said valve body, a valve stem, a plug at the lower end of said connection, said stem having a close sliding fit through said plug, valves on said stem adapted to engage said seats, fluid pressure operated means to move said valve stem and valves, and a tapered governor pin on the lowermost of said valves projecting into said lower opening.

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